1950

A Study of the Conditions Affecting Costs of Delivering Electricity to Rural Areas Through Central-station Service

Frank Wiersma

A STUDY OF THE CONDITIONS AFFECTING COSTS OF DELIVERING ELECTRICITY TO RURAL AREAS THROUGH CENTRAL-STATION SERVICE

By

Frank Wiersma

A Thesis Submitted
to the Faculty of South Dakota
State College of Agriculture and Mechanic
Arts in partial fulfillment of the requirements for
the degree of Master of Science

May 1950

This is to certify that, in accordance with the requirements of South Dakota State College for the Master of Science Degree, Mr. Frank Wiersma has presented to this committee three bound copies of an acceptable thesis, done in the major field; and has satisfactorily passed a two-hour oral examination on the thesis, the major field, Agricultural Engineering, and the minor field, Agricultural Economics.

May 29, 1950
Date

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

One of the most common sources of power in this country today is electricity. It is undisputed in its claim as leader because of its versatility, efficiency, cleanliness, and applicability to a large number of uses. Not only the cities, but small villages and individual farms as well can now receive the benefits of this amazing source of light and power. Through the efforts of corporations producing small individual power plants and of the men who encouraged and promoted the beginning and expansion of central-station service for large rural areas, almost every farm can now have electricity to help him in more convenient and efficient agricultural production.

The tremendously rapid growth of electricity as a source of power has been paralleled only by the expansions of products that were produced in part by the use of this electric power itself. This expansion has not reached its goal, nor has it stopped; for even today lines are being constructed in rural areas whose inhabitants, in years past, never dreamed that they too would be allowed to enjoy the benefits of electricity. In addition to this increase in electric power consumption due to expansion into new fields, consumption is also constantly growing in areas where the power has been available for years. Few appliances are ever taken off the line but new and larger ones are continuously being added.

This one development -- electricity -- can be given credit to a large extent for the growth and development of the nation as a whole for a continual rise in the standards of living of its people.

REASONS FOR THIS STUDY

A limiting factor of installing electric power on farms, especially in the more thinly populated areas, is the initial and annual cost of providing this electricity. In view of this fact, this study has been made to determine the costs of various methods of providing electrical power to these farms and the various physical and economic factors that have an effect on these costs.

Some farm operators, when considering the installation of electricity, look only at the cost without considering the benefits and increased financial returns. Some operators, on the other hand, can see only the benefits of electricity without stopping to realize that unless initial and operation costs are justified they will receive only added expenses and may not be able to continue the operation of their source of power. Proper utilization is an important factor in an electric power unit installation that will pay for itself.

Farmers who have no electricity available at the present are faced with the question of what type of electric power source should be installed. Should he install an individual wind or internal combustion engine plant, or should he wait until a central-station source of power is available? For those who have had an individual plant for some time, but have since had a central-station source made available to them, the question arises as to whether or not they should change their source of power.

In order to answer these questions it is necessary to know the financial costs of all methods available and balance these with the benefits that may be received from each source. To know this, a study must be made of the various factors that have an appreciable effect on the various costs. This study is primarily made to ascertain the conditions affecting the costs of delivering the electricity to rural areas through central-station service.

An individual plant as a source of power will provide almost the same amount of returns at a given cost in one territory as it will in another. For this reason more accurate figures can be obtained on the cost of a given type of individual plant than can be obtained for the cost of central-station service. The rates to be charged will depend on a number of factors, each one of which will vary in different areas. This study has been made in an attempt to determine which factors influence the retail rates that the consumers pay and to what degree they are affected by each.

HISTORY OF ELECTRICITY AS A COMMON SOURCE OF POWER

Since the discovery and development of electricity as a practical servant of man, there have been primarily two phases of its growth -- that of the urban districts and the later development of the rural areas. The urban districts were the first to receive the benefits of electricity with its beginning at Thomas A. Edison's Pearl Street Station in New York, which began its operation on September 4, 1882.

The development and expansion in its early stages were naturally slow and were hindered by lack of knowledge of the operators, but after it had established itself in the minds of the public as a desirable source of light and power, its expansion was extremely rapid. Its increase in demand was paralleled by improvements in methods of transmission.

The first electricity generated by the Pearl Street Station was used for street lighting. For some years this service was made available only to limited areas within a city, but as time went on the art of generating and distributing electricity progressed, finally making the service available to all parts of both large and small cities.

The first alternating-current generating plant in America was erected in Great Barrington, Mass., in 1886. This plant demonstrated how electric power could be generated at low voltage, stepped up by means of transformers to a higher voltage, transmitted at this higher voltage, and later stepped down by means of transformers to a lower voltage for utilization purposes. This development was a great boon to the rapid expansion that was to follow.

It is significant to observe that during the first years of development of the electric-power industry the power companies were interested primarily in selling light. In view of this fact, it is not surprising that the first rates for incandescent lighting as established by Edison in New York were based primarily upon the cost of lighting by gas. In 1883, the electric rate was equivalent to about 24 cents per kilowatt hour, and dropped to about 20 cents per kilowatt hour in 1890. Just before the turn of the century, the Edison Company in New York established its rates on a kilowatt hour basis. Since that time the kilowatt hour has been, for rate making purposes, considered the basic unit of electric energy. The term kilowatt hour is defined as a measure of electrical energy equal to the work done by a current of 1000 watts acting for 1 hour.

Electrical energy gradually found its way into use as power beginning in 1884. Investigation reveals that various industrial motors as well as electrically driven fans were first used during that year. In 1886, electric power was being supplied to about 30 motors in various parts of the city of Boston at a rate of 150 dollars per horse-power per year. In 1887, rates for motor operation were changed to a monthly basis.

Since that time the electrical industry has grown with almost phenomenal rapidity until at present it occupies an important place in the economy of the nation. The developments and technological advances are too numerous and not within the scope of this study, but it would be well to remember that the unparalleled progress of the electrical industry as a whole preceded the developments in rural electrification and made them possible.

HISTORICAL DEVELOPMENT OF RURAL ELECTRICITY

One of the first recorded uses of electricity on the farm in this country was at Ellerslie, a farm in Dutchess County, New York. The electric installation consisted of two dynamos driven by steam engine used in conjunction with a storage battery consisting of 67 cells. The main uses of power were for lights, for pumping water, and for the fire alarm system.

The use of central-station electric service on farms in this country got its greatest impetus in California. During the period 1900 to 1910 farmers in this state began to make extensive use of electricity for irrigation pumping. The use of central-station electric service gradually spread, and by 1912 lines with voltages as high as 2300 volts were serving a few farmers around the territory near Greenville, Pennsylvania.

For the most part, the first lines from which farmers were able to obtain service were either lines connecting villages and towns, or short extensions of the town or city distribution systems. It is only natural that those areas which offered the highest returns on investment were generally served first. In many cases it was necessary for farmers themselves to finance the construction of lines through rural territory. This initiative on the part of the farmers proved the demand for rural electricity.

Many agricultural and industrial leaders early recognized the desirability of using central-station service on farms wherever possible. In 1916, an outline was made of a number of uses for electricity on the farm and utilities were urged to develop ways of supplying electric energy to farms on a basis which would make it economically feasible for the farms to use it. About this time there was some discussion relative to merits of central-station service as compared to individual farm electric plants. The individual plants made a very substantial contribution to the rural electrification program during the early days of the movements. While recognizing their importance, it was noted that they were expensive and that power loads required central-station service.

There was a great upsurge of interest in rural electrification during the decade between 1920 and 1930. In 1922 farm people were beginning to demand central-station service, and utilities had no familiar or organized method of rural distribution. The high cost of supplying central-station service to rural customers, together with the economical utilization of the service once it had been made available, were recognized as important factors affecting the development of the whole program.

It is generally conceded that little had been done from either the distribution or the farm application standpoint in the rural electrification field in this country prior to 1923. During that year the national Committee on the Relation of Electricity to Agriculture (CREA) was formed. This committee consisted of representatives of farm organizations, electric utilities, electrical manufacturers, the American Society of Agricultural Engineers, and state and federal agencies. The committee concluded that since little organized information was available on the use of electricity on farms, it would be well to establish an experimental rural line in order to collect data which would guide them to future activities. As a consequence, formation of the Red Wing Project under the sponsorship of the national CREA was announced late in 1923. A five-mile experimental line through a farm community in Minnesota was planned. Exact records were kept so that data regarding line costs, operating, upkeep, and farm products output before and after electrification would be available.

Between 1923 and 1927 cooperative agencies for doing investigational work in the field of rural electrification were established in 23 states. Most of the investigational work was done by, or in conjunction with, the state agricultural colleges. Ralph L. Patty, Head of the Agricultural Engineering Department of South Dakota State College and the State College Experiment Station at Brookings, were instrumental in obtaining information on costs and uses of electricity on South Dakota farms from a test line near Renner, South Dakota. The original line was 8.4 miles long and had 17 farms connected to it. The purpose of the electric test line and the studies were to find out what the electricity would cost for various farm purposes and how it would effect the operation of the farm. Power compaies were vitally interested in how much electricity could be used on an average farm.

In considering other developments which took place during the decade prior to 1930, the recommendation for the formation of a rural electrification division in the American Society of Agricultural Engineers is noted. About this time and shortly thereafter, a number of commercial organizations became quite active in promoting various rural electrification activities. Finally, an idea of the progress made may be gained from a report which showed that the number of farms receiving "high line" service had increased about three times during the period from 1924 to 1929. Most of these lines were extensions of the urban distribution systems.

By January 1931, the proportion of farms receiving electric service had reached 10.2 per cent. During the ensuing four-year period 1931 to 1934, progress was less notable, with fewer than 100,000 additional farms receiving service -- an increase of only 0.7 per cent.

In the meantime the Tennessee Valley Authority which has done much to promote the development of rural electrification in its territory, was established by an act of Congress on May 18, 1933. As a part of the full development of the natural resources of the Tennessee River area the TVA was authorized to sell the surplus power generated at its dams for the benefit of the people of the section as a whole, particularly the domestic and rural customers to whom the power could economically be made available.

Rural electrification was included as one of the classes of approved projects under the Federal Emergency Relief Appropriations Act of 1935. On May 11 of that year the president, by executive order, created the Rural Electrification Administration "to initiate, formulate, administer and supervise a program of approved projects with respect to the generation, transmission and distribution of electrical energy in rural areas."[1] Primarily the Rural Electrification Administration was established to make loans for the purpose of building distribution lines in order to make electricity available to farmers who were able to use the service, but who had been without it. It was authorized to make 20-year loans to farmers' cooperatives, public power districts, private utilities, and to other agencies.

During the middle thirties long-span lines came into rather general use. Instead of the customary 30 to 35 poles per mile these lines used only 18 to 20. This reduction in the number of poles required, improvements in operation techniques, improvements in equipment, and other economies have resulted in a gradual reduction in the cost of electrical distribution in rural areas. Because of more favorable operation costs a number of utilities found it feasible to build rural lines into territories where the customer density was only three per mile, and in some even less.

---

[1]Coyle, David Cushman. Electric Power on the Farm, Rural Electrification Administration, U. S. Government Printing Office, Washington, 1936. p 90.

According to data released by the Edison Electric Institute, more than a million farms were connected for central-station service by the end of 1936 and over two billion kilowatt hours of electricity were being used annually by American agriculturists. As an indication of the intense interest in rural line construction about this time, it is pertinent to observe that the REA allocated $76,391,019.50 during the period between January 1, 1936 and June 30, 1938 for rural line construction.[2] Privately owned utilities were extremely active in promoting rural line construction during this period also.

In 1938 a research project in rural electrification was established in the Bureau of Agricultural Engineering of the United States Department of Agriculture. In general the research activities engaged in were conducted through and in cooperation with selected experiment stations of the land-grant colleges.

In 1941 over two million farms were connected for electric service. This meant an increase of approximately 100 per cent over the number of farms being served in 1936. Rural line construction costs had been significantly lowered and new methods of low-cost financing, both public and private, had been devised, but there was still much rural territory that could not, under existing conditions, be economically served.

---

[2] "Report of Rural Electrification Administration," 1938. p 258.

Much of this territory not yet served was in areas not as heavily populated as those areas that had been electrified. It was doubtful at that time that the revenue received from the relatively few consumers in this area would be sufficient to permit operation on a self-liquidating basis. Perhaps the one chief answer to this problem was provided by the Connecticut state legislature when it provided and passed a bill which is referred to as the "two per mile bill". The bill reads as follows:[3]

> Sec. 619f. (1941) (a) Extension of electric lines to unserved areas. The public utilities commission shall order and direct the electric utility companies distributing current in this state to extend lines on their chartered territory, to all unserved areas having a density of subscribers for electric service averaging at least two per mile on such proposed new lines, in accordance with the provisions of this section. (b) Determination of rates. The public utilities commission is directed, in considering the rates of electric utility companies in this state or in the proceedings having to do with such rates, to consider the expenses and revenues of each company as a whole, in arriving at a fair return on the fair value of such properties. In prescribing a rate for service on such new lines, the commission shall exercise its statutory powers, except that the guarantee required shall not exceed thirteen dollars and fifty cents per mile per month. (c) The commission is directed to advance the objects of this section in every lawful manner. Effective June 18, 1941.

The Connecticut utilities have considered each area to be served as one project in lieu of considering each individual extension separately. This enables more farmers to qualify for and take advantage of electric service.

---

[3] Earp, Unus F. Rural Electrification Engineering. McGraw-Hill Book Company, Inc. 1950. p 10.

The growth of electric service in rural areas from central-station service brought about a new field in manufacturing in the form of electric appliances. The appearance of these appliances in turn provided a demand for electricity in the areas where it was not feasible to run lines from a central-station. For this reason, a large number of individual farm electric-plants came into use throughout the country.

Various methods were used to power the small electric generators used for supplying power to individual farms. Windmills, water wheels and internal combustion engines were the most common methods in use. With few exceptions the actual power available from such units is 5000 watts or less. This low power output has long been recognized as a limiting factor in the program for complete farm electrification. It has also been discovered in this study that in almost all cases, central-station service is much less expensive and offers a greater diversity of application. Even so, there were approximately a quarter million farms in the United States having their own individual electric plants on January 1, 1936.[4]

---

[4]Federal Power Commission Electric Rate Survey, Rate Series 8, February 1, 1935.

COST OF ELECTRIC ENERGY

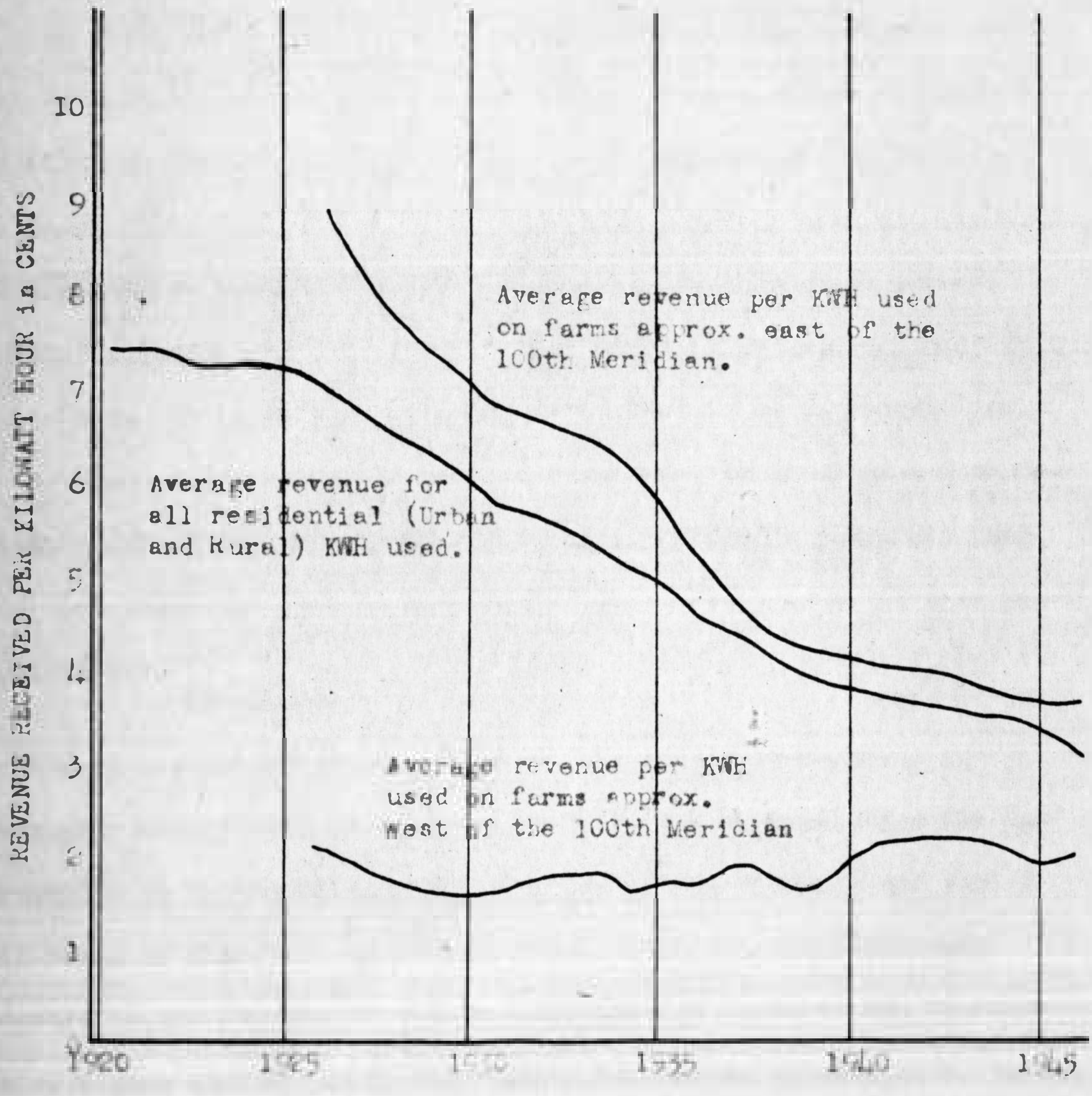

Fig. 1. Cost of electric energy for domestic and rural uses. (Courtesy of Edison Electric Institute.) As printed in Rural Electrification Engineering. By Truman E. Earp. McGraw-Hill Publishing Company, Inc. New York. 1950

IMPORTANCE OF RURAL ELECTRIFICATION

In order for a farm to realize the greatest return it must operate with the greatest efficiency. This efficient application of power in agricultural production is essential to the success of the farm as a business enterprise. Electricity -- a clean, easily handled, versatile, and inexpensive source of power -- can mean the difference between profitable production and economic insufficiency in some types of farm businesses. It is common knowledge that power is an important factor in the cost of production at any time, and that it is of even more importance during periods of high labor cost. Electric power has long been recognized as being ideally suited to a large number of farm power applications.

Rural electrification, as viewed in its broader aspects, is singularly peculiar in that it offers unlimited possibilities for improvements in the standards of living and in the economic and social well-being of the farm people it serves. Farm refrigeration made possible by the availability of electricity (1) lends to the production of higher quality milk, (2) enables the farmer to slaughter, chill, and store his meat at times of his own choosing, and (3) enables the farmers to harvest, process, store, and market his fruits and vegetables at times favorable to his economic advantage. These factors not only benefit the farmer who produces the goods, but gives the consumer products of better quality at a lower price. This indirectly has a favorable effect on the standard of living of the people of the nation.

Electrically operated brooders, sterilamps, water warmers, lights and other items provide the poultryman with efficient production tools which save him labor and result in lower production costs. Efficient and highly versatile electric tools and devices are available to essentially every phase of agricultural production. That these electrical aids to farm production and rural living, result in higher farm income, more favorable working conditions, more favorable conditions for rural youth developments, and a multitude of other favorable conditions, which directly or indirectly contribute to the betterment of our people as a whole, is a foregone conclusion. That the developments in, and the progress of, rural electrification are highly significant in the broad economic and social picture of modern life, in relation to both rural and urban population, is an unquestioned fact.

A rural electric system from a utility standpoint is a business enterprise which is based on either private capital or public capital or both, and which is expected to be economically self-sufficient. It is semi-monopolistic in character and hence is of vital concern to the public. In order for the enterprise to remain in existence it must operate on a sound financial basis. Improved designs, developments in construction methods, and developments in equipment have resulted in reductions in the construction costs of rural lines, thereby making it economically feasible to serve areas once thought a poor investment.

The first lines extending into rural areas were placed in the districts of higher population density where the possibility of sufficient returns to handle costs was more feasible. However, these lines served as research developments themselves in the experience and knowledge that was gained in their construction and operation. As the rural lines extended on into less densely populated areas, improvements in construction and operation cut the costs, enabling the fewer number of consumers to receive power without paying excessive prices.

Approximately one-third of the customers of the entire electric light and power industry reside in rural areas and in communities having a population of 2500 or less. Manifestly, the use of electricity exclusively for lights would likely be extremely unprofitable for both the utility and the farmer. Recognizing this fact, utilities have not only assisted in developing ways and means of profitably applying electricity to agricultural production, but they have also made noteworthy progress in the realm of consumer education.

From the utility standpoint, successful operation and management are highly dependent upon the maintenance of good will with the customer. With adequate system capacity and with properly trained personnel there should be no question regarding the type of service made available. Good will can be created and fostered by educating the public in problems of supplying electric service by supplying adequate uninterrupted service, by proper publicity, by using equitable and uniform rates and a uniform billing system, and by the proper regard of the rights of the customer while maintaining and servicing lines and equipment.

From the farmers point of view rural electrification in its broader aspects is likewise a business enterprise. One does not minimize the importance of electric lights and the ordinary domestic uses of electric power. At the same time, complete rural electrification can be achieved only through the recognition of the value of utilizing electric power on a business basis. Power is used successfully in any thriving production process only so long as the use of that power yields adequate returns. These returns need not necessarily be measured on a dollar basis. The elimination of various types of hazards to health, the elimination of drudgery, the promotion of efficiency, and various other benefits may be considered as adequate to offset the various expenses involved.

To fully realize the cost of delivering the electric power to a farmer, it is essential to understand, in part at least, what it takes to produce and deliver this power. One must have some concept of the organization and individual functions of the parts of a rural electric system.

Basically, a rural electric system must consist of three fundamentals: (1) physical facilities, (2) personnel for administration, operation, and maintenance, and (3) finances or capital. Physical facilities include a source of power, which may either be a plant now in operation from which the power may be purchases, or it may be the possibility of construction of a plant with which a concern can generate its own electricity. It also includes a source of consumption to provide a demand for the power that is produced and a means of delivering this power to the consumer. Personnel for administration, operation, and maintenance are responsible for the construction and operation of the physical facilities that are obtained. Finances or capital is the acquiring of a source of money with which to build and to operate a rural electrification distribution system.

The financing problems of a power supplier are numerous and sometimes extremely difficult to solve. Every power supplier, regardless of ownership, is vitally interested in financial stability. Naturally, as in any other organization, to survive, a power supplier must operate on a sound financial basis. A perspective of costs of an organization will show the various costs under two main headings which might be termed as initial investment costs and cost requirements in the operation of the system. Under initial investment costs are included such items as:

1. Cost of original surveys. This includes the surveys for transmission and distribution lines, substations, and generation facilities.

2. Economic studies. These include costs of original and all subsequent studies dealing with the economic feasibility of making investments on any part of the system.

3. Physical plant. This includes cost of generating facilities, transmission and distribution lines, substation equipment, and office equipment.

4. Miscellaneous equipment required for customer service. This includes cost of such items as distribution transformers, service drops, meters, and other smaller articles.

This list may not include every cost but will serve as an overall guide as to the costs involved. These costs must be covered by the revenues received from the consumers who are utilizing the power that is being produced and distributed.

In the final analysis a basic knowledge of the financial structure of a utility is necessary for a proper appreciation of the manegerial problems incident to the financing of rural electrification systems.

PREVIOUS WORK COMPLETED ON RURAL ELECTRIFICATION COSTS

In an effort to establish some idea on the comparative costs of individual farm power plants tests have been performed on various kinds of plants. The tests made at South Dakota State College were on automatic gasoline electric plants of two capacities and on a 110-volt wind-powered plant.

Loads simulating typical farm loads in amount and nature, were used in the tests. A daily consumption of five to six kilowatt hours was used as normal for a farm with an individual power plant of this size. The cost of furnishing power for the farm included, in the case of the automatic gasoline plants, the cost of the fuel consumed, the labor for refueling, cost of oil, repairs and labor for servicing, the depreciation on the plant, and the interest on the investment. These costs were found for each of various daily consumption figures and for the combination of all consumption loads. These costs are shown in Figures II and III.

The larger loads consumed more fuel for the total load, but the cost per kilowatt hour decreased as the consumption increased. This was true for both sizes of automatic gasoline plants, as shown in Figure IV. However, the average cost per kilowatt hour for both plants was very much higher than normal rates from central-station service. The larger plant did, nevertheless, generate the power at a lower cost than did the smaller plant.

OPERATING COSTS FOR 3000 WATT POWERLITE PLANT

WITH

VARIOUS DAILY CONSUMPTION

KWH daily consumption	TOTALS			COSTS PER KILOWATT HOUR							
	KWH generated	Hours run	Cost of fuel consumed	Fuel consumed	Labor for refueling	Oil	Repairs	Service and repair labor	Depreciation	Interest on investment	TOTAL COST
4	48	84	6.43	.1340	.0125	.0245	.0044	.0188	.1312	.0200	.3478
5	110	154	13.49	.1226	.0099	.0158	.0035	.0150	.1050	.0164	.2883
6	210	245	21.38	.1018	.0083	.0163	.0029	.0125	.0875	.0137	.2431
7	56	56	5.19	.0926	.0071	.0139	.0025	.0107	.0750	.0117	.2137
8	24	21	2.08	.0867	.0062	.0121	.0022	.0094	.0656	.0103	.1924

OPERATING COSTS FOR ALL LOADS

DURING ENTIRE PERIOD JANUARY 8, --- MAY 26, 1949

	840	957		.1084	.0083	.0138	.0018	.0071	.0833	.0138	.2360

Note: Daily running time assumed constant at seven hours

Fig. II. Operating costs for automatic gasoline plant. (1500-watt)

OPERATING COSTS FOR 1500 WATT POWERLITE PLANT

WITH

VARIOUS DAILY CONSUMPTION

	TOTALS			COSTS PER KILOWATT HOUR								
KWH consumed daily	KWH generated	Hours run	Cost of fuel consumed	Fuel consumed	Labor for refueling	Oil	Repairs	Service and repair labor	Depreciation	Interest on capital		TOTAL COST
3	30	70	3.74	.1245	.0167	.0326	.0207	.0213	.2352	.0230		.4740
4	152	266	19.09	.1256	.0125	.0245	.0156	.0160	.1764	.0172		.3877
5	150	210	18.68	.1245	.0100	.0196	.0124	.0128	.1414	.0138		.3392
6	246	287	24.07	.0978	.0083	.0163	.0103	.0106	.1176	.0115		.2726
7	56	56	7.06	.1260	.0071	.0140	.0088	.0091	.1005	.0099		.2757

OPERATING COSTS FOR ALL LOADS

DURING ENTIRE PERIOD JANUARY 11 --- JUNE 5, 1949

	645	1225	74.28	.1152	.0136	.0087	.0136	.0140	.1940	.0187		.3750

Note; Daily running time assumed constant
at seven hours

Fig. III. Operating costs for automatic gasoline plant. (3000-watt)

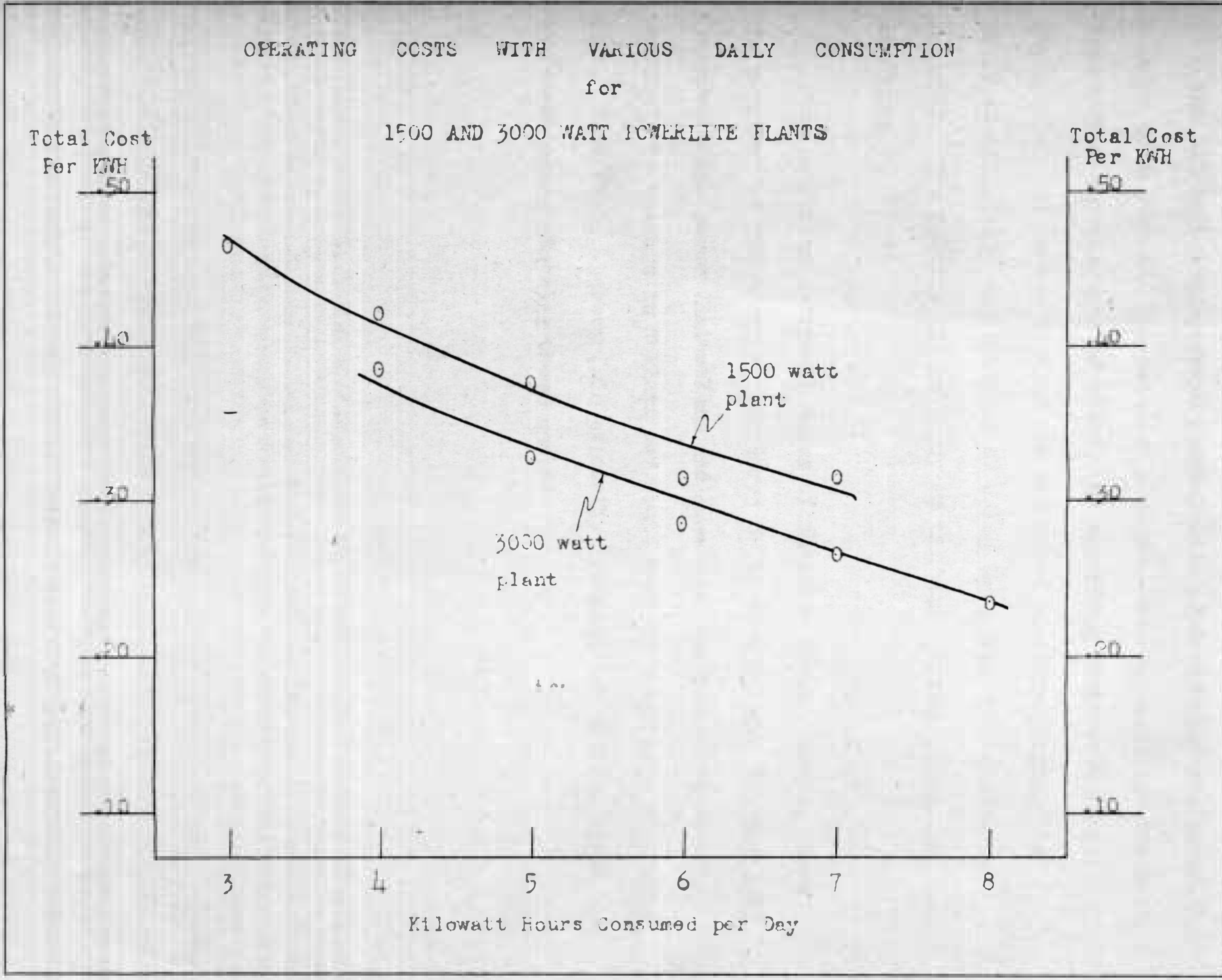

Fig. IV. Curves showing decrease in unit operating costs with increase in daily consumption.

The 110-volt wind-powered plant tested produced electric power at a lower cost than did the gasoline plants. Initial costs and interest were higher on this type of plant, but operating costs were almost negligible. As in the case of the automatic gasoline plants, the greatest efficiency was obtained by using the plant at its maximum capacity. The results of the study on the wind-powered plant are shown in Figure V.

When comparing different types of electric power sources, there are a number of items other than costs to be considered. Convenience, dependability, power limitations and scores of various other factors difficult to measure in dollars and cents must be taken into consideration. This study, however, is primarily intended for various costs and the conditions affecting these costs.

OPERATING COSTS FOR WINCHARGER PLANT

FIRST COST
- Plant & Tower $1300.00
- Batteries $ 822.00

LIFE
- Plant & Tower 20 years
- Batteries 10 years

	ANNUAL COST	COST PER KWH
INSURANCE ON PLANT		
Fire, Lightning, Windstorm, Tornado & Hail. $500	27.00	.0133
INTEREST ON INVESTMENT 6%		
Plant & Tower	39.00	.0199
Batteries	24.00	.0118
DEPRECIATION		
Plant & Tower	65.00	.0321
Batteries	82.20	.0406
SERVICE & REPAIRS	5.50	.0027
TOTAL COST	242.70	.1198

Fig. V. Operating costs for 110-volt wind powered electric power plant.

INVESTIGATION AND ASSUMPTIONS

For the purpose of determining the possible conditions in existence which have an effect on the retail rates of various individual REA cooperative associations, a study was made from the annual reports of a number of cooperatives from different parts of the United States. These reports give a complete listing of the operations of each cooperative association. In calculating the rates for each individual cooperative, the arithmetic mean rate was found by dividing the total number of kilowatt hours sold in a given period of time by the total amount of revenue received from the sale of this power.

As was mentioned in the history of rural electrification, improvements were made in the efficiency of distributing this power as power was supplied to more and more consumers. The question arises that if this were true when electric power for farmers was in the earlier stages of development, would it still be true in the development of individual cooperative associations today? To answer this question, a study was made of the power sales of five associations in each of seven states over a period of four years from the year 1945 through 1948.

Age Of Cooperative Versus Rate

After examining the results of plotting the rates of each cooperative for the four-year period it is safe to conclude that at least while a cooperative is still growing, rates decrease as the associa- becomes older. Some of the charts show an occasional increase in rates

CHRONOLOGICAL RATE TRENDS FOR VARIOUS COOPERATIVES

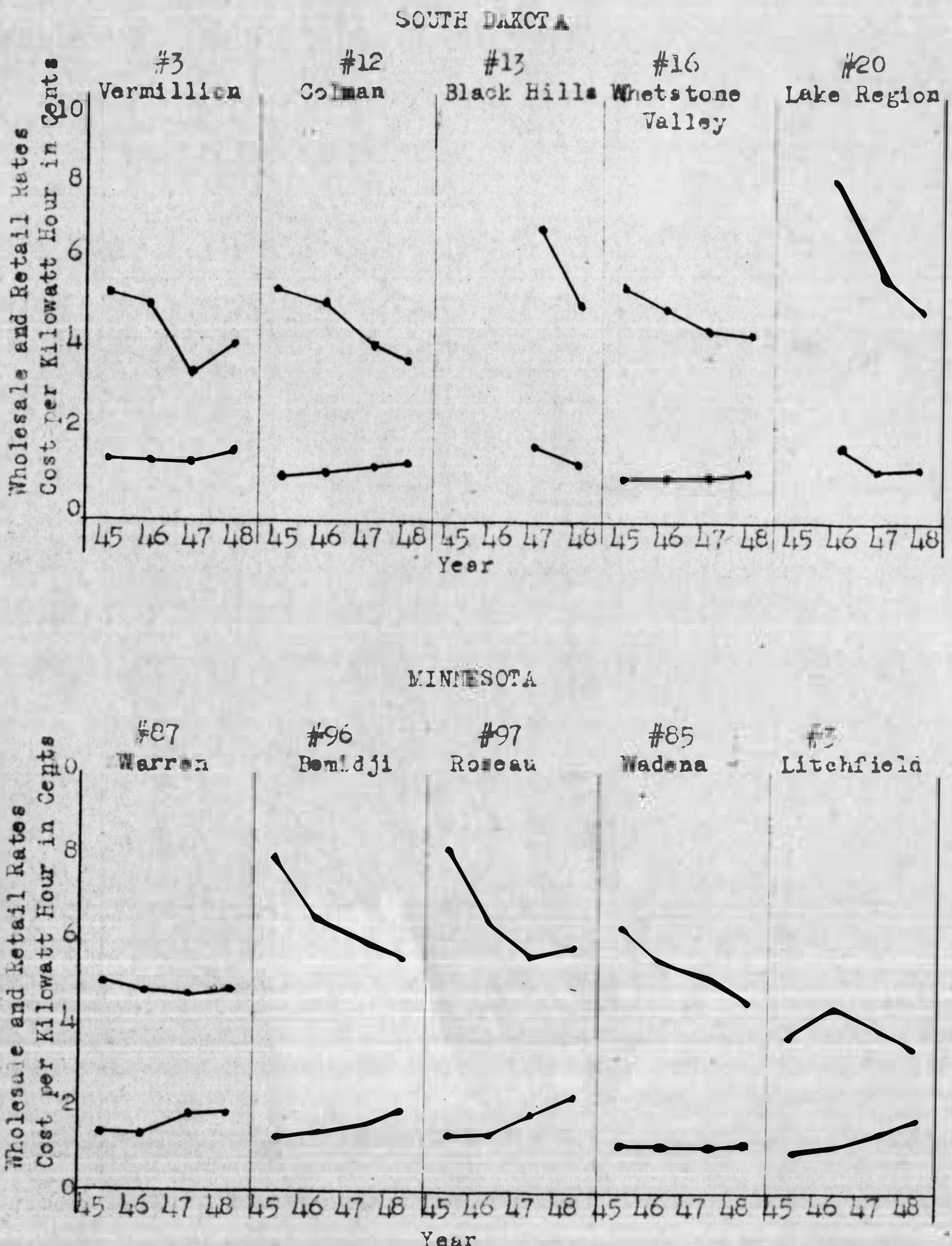

Fig. VI. Charts showing the average rate charged by each cooperative association for the year indicated.

CHRONOLOGICAL RATE TRENDS FOR VARIOUS COOPERATIVES

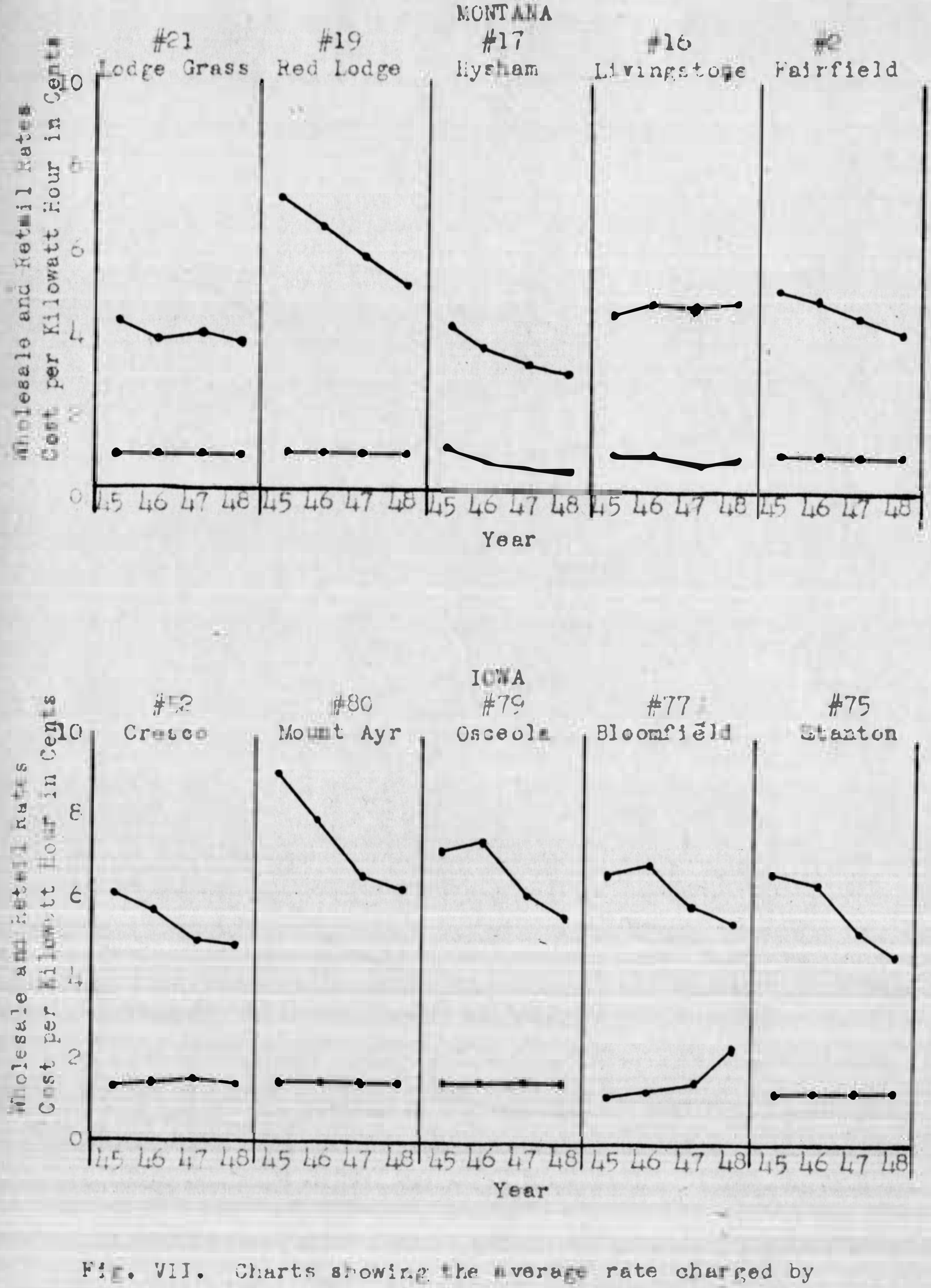

Fig. VII. Charts showing the average rate charged by each cooperative association for the year indicated.

CHRONOLOGICAL RATE TRENDS FOR VARIOUS COOPERATIVES

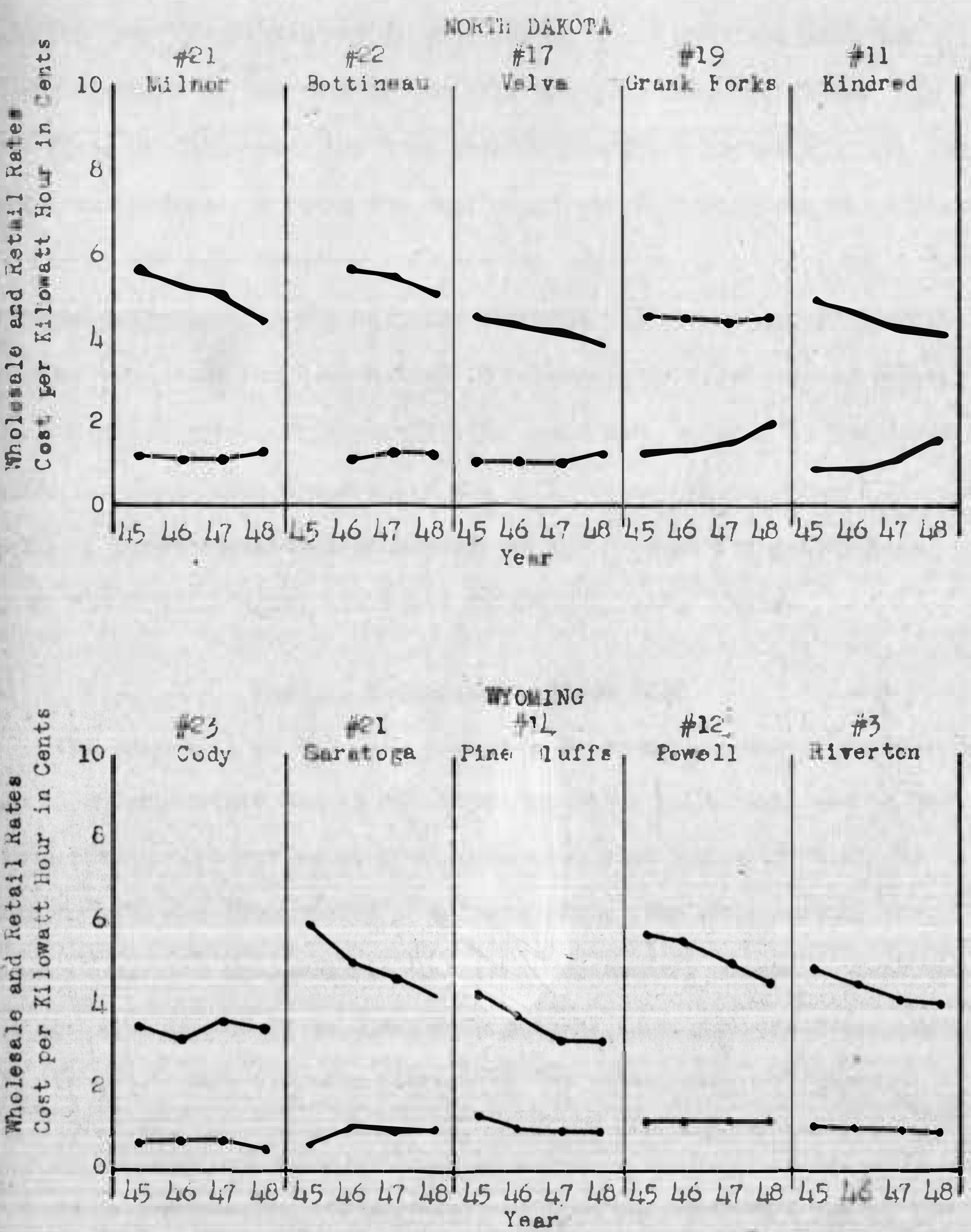

Fig. VIII. Charts showing the average rate charged by each cooperative association for the year indicated.

for a short period of time. This is probably due to other causes, depending upon the conditions in existence. It is possible that the administration of one association (for example, Cooperative No. 3 in the State of Minnesota) may have established their prices too low, and tried an increase in rates the following year to accelerate the liquidation of the debt incurred. Or, on the other hand, a cooperative with a financially sound setup may have declared a decrease one year which brought the rates too low, making it necessary to increase the rates the following year. This possibility could have existed in the curve shown for Clay-Union Cooperative No. 3, in South Dakota, Figure VI. In spite of these occasional increases, as the cooperative association grows older and larger, the rates in general become lower.

Size of Cooperative Versus Rate

The results from the data gathered to determine whether or not the age of a cooperative has an effect on the rates would lead one to believe that a cooperative with a larger number of consumers would be able to sell the electricity at a lower rate. For this reason, the sizes of various cooperatives (number of consumers) within a state was plotted against the rates charged by each of these cooperatives, Figure IX. To get a more accurate picture of the relationship of these plotted points, an equation for a regression line[5] was calculated and

---

[5]A regression line is defined as a line such that the sum of the squares of the distances of the arithmetic means of the columns, from the regression line, each mean counted as many times as there are items in the column, is the least possible. If some other line were drawn, the sum of the squares of the distances from it would be more than when this regression line is used.

SIZE OF COOP vs. RATE

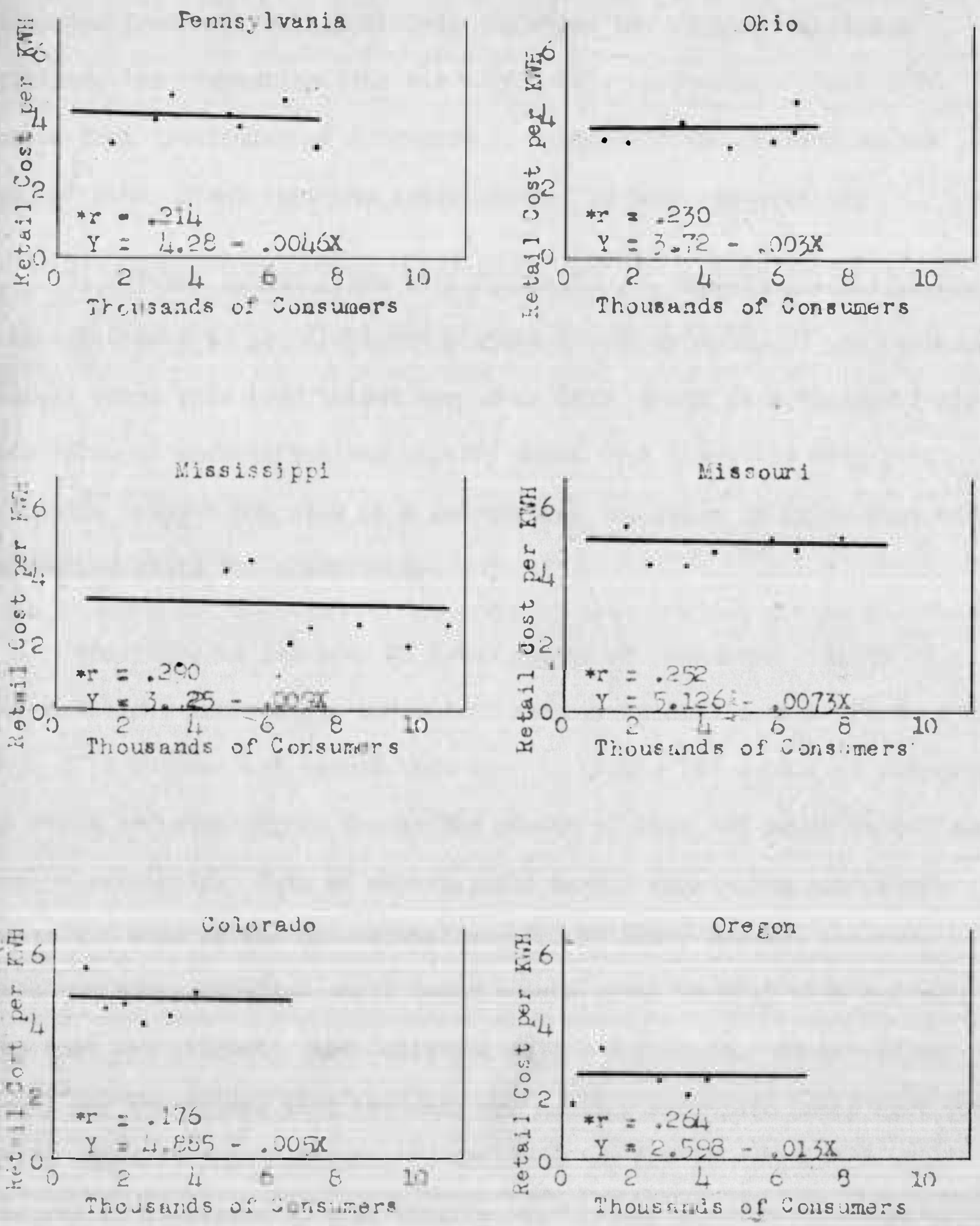

Fig. IX. Regression lines showing the effect that the number of consumers within a coop has on the retail rates charged by coops from various states. *r indicates correlation coefficient. Y indicates equation of line.

then plotted to represent these points. A group of cooperatives were selected from each of six states. In every one of the six states plotted, the regression line was very nearly horizontal. This indicates that the number of consumers in a cooperative association has no definite effect upon the rates charged by that cooperative.

To further substantiate this conclusion, a correlation coefficient was calculated to get a clearer picture of the grouping of the points. In all cases this coefficient was .3 or less, which is a comparatively low value of correlation and clearly shows that there was very little relation between the size of a cooperative and rates at which that cooperative sells its electricity.

Evidently, an increase in total number of consumers results in a proportionate increase in investment and operational costs. That is to say, if a cooperative association were to double its number of consumers, it would be necessary to double the amount of line and power to deliver this electricity. This of course would nearly double the investment costs and some of the operational costs. It would appear, however, that the administration costs could remain quite stable, thus reducing the cost per kilowatt hour delivered to the customers. On the other hand, any expansions that are made are usually made into areas that include somewhat less desirable territory -- as far as delivering electricity is concerned -- than those areas already served. For instance, the farming land surrounding or adjacent to the present area of the cooperative may be less densely populated than the land included in the cooperative. Such conditions appear to compensate for any rate decrease that is acquired by increasing the number of consumers in a cooperative.

Density Of Consumers Versus Rate

This last assumption brings about another question. Does the density of a cooperative have an appreciable effect on the retail rates that are charged by that association? It would seem logical that the more consumers served by the installation of a mile of line, the cheaper would be the unit cost of delivering the electricity to these consumers. The cost of a mile of line is not affected to a great degree by the number of consumers that are to be served by that line. This decrease in initial cost per consumer would result in a decrease in retail cost per kilowatt hour delivered.

To determine whether or not this is true, rates charged by the cooperatives from each of 13 states were plotted against the density of consumers in the corresponding cooperative, Figure X. A regression line and correlation coefficient was again calculated for each group of points. In general the assumption that lower rates are charged where the consumer density is higher is true, but does not hold in all cases. In the western and southern areas where there is a large variation in consumer density of different cooperatives of a given state, the more heavily populated cooperative associations sold their power at a lower rate than did the more sparsely populated organizations of the same state. However, in the midwestern areas including the states of Iowa, DENSITY OF CONSUMERS vs. RATE

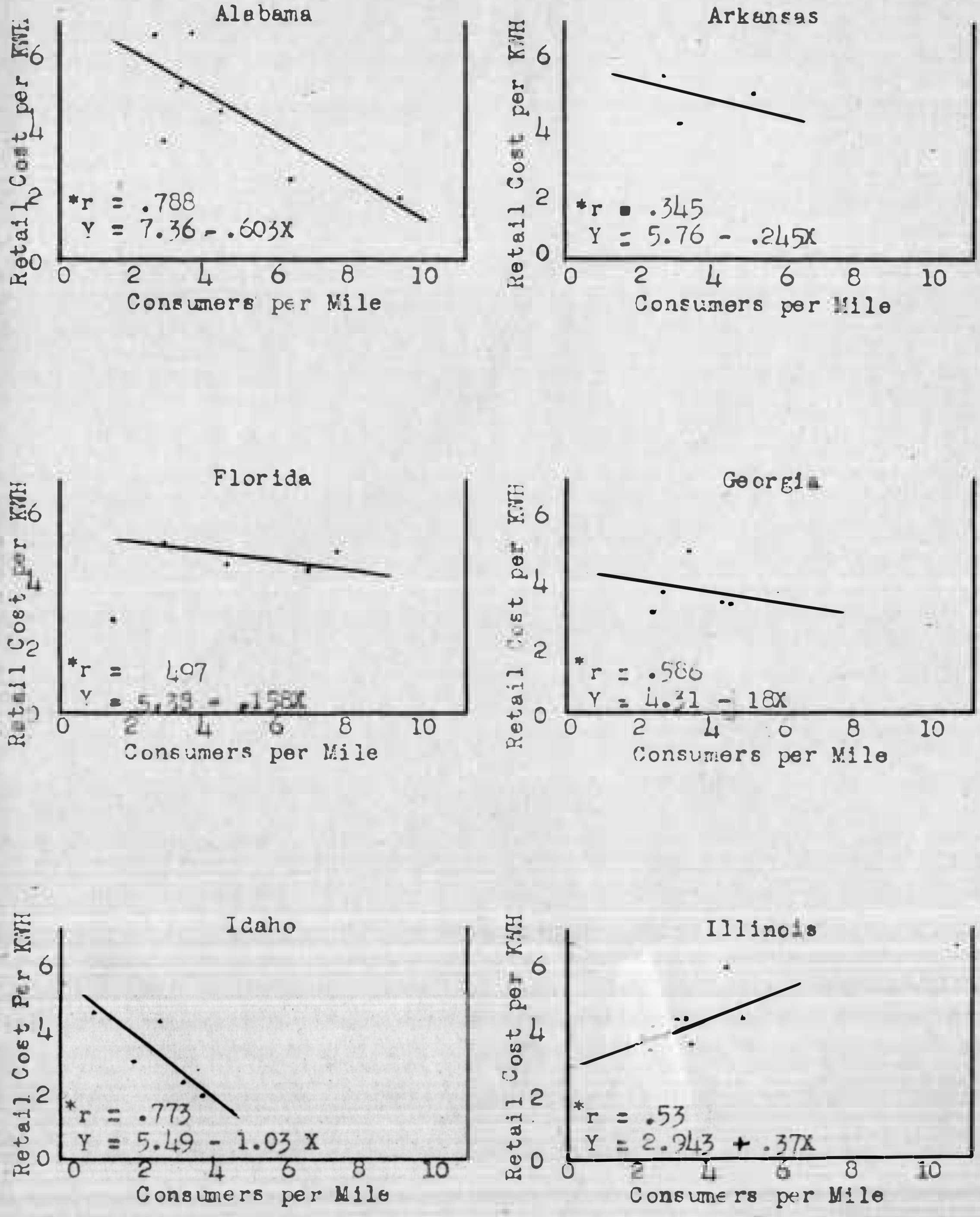

Fig. Xa. Regression lines showing the effect that density of consumers has on retail rates charged by coops from various states. *r indicates correlation coefficient. Y indicates equation of line.

D E N S I T Y O F C O N S U M E R S vs. R A T E

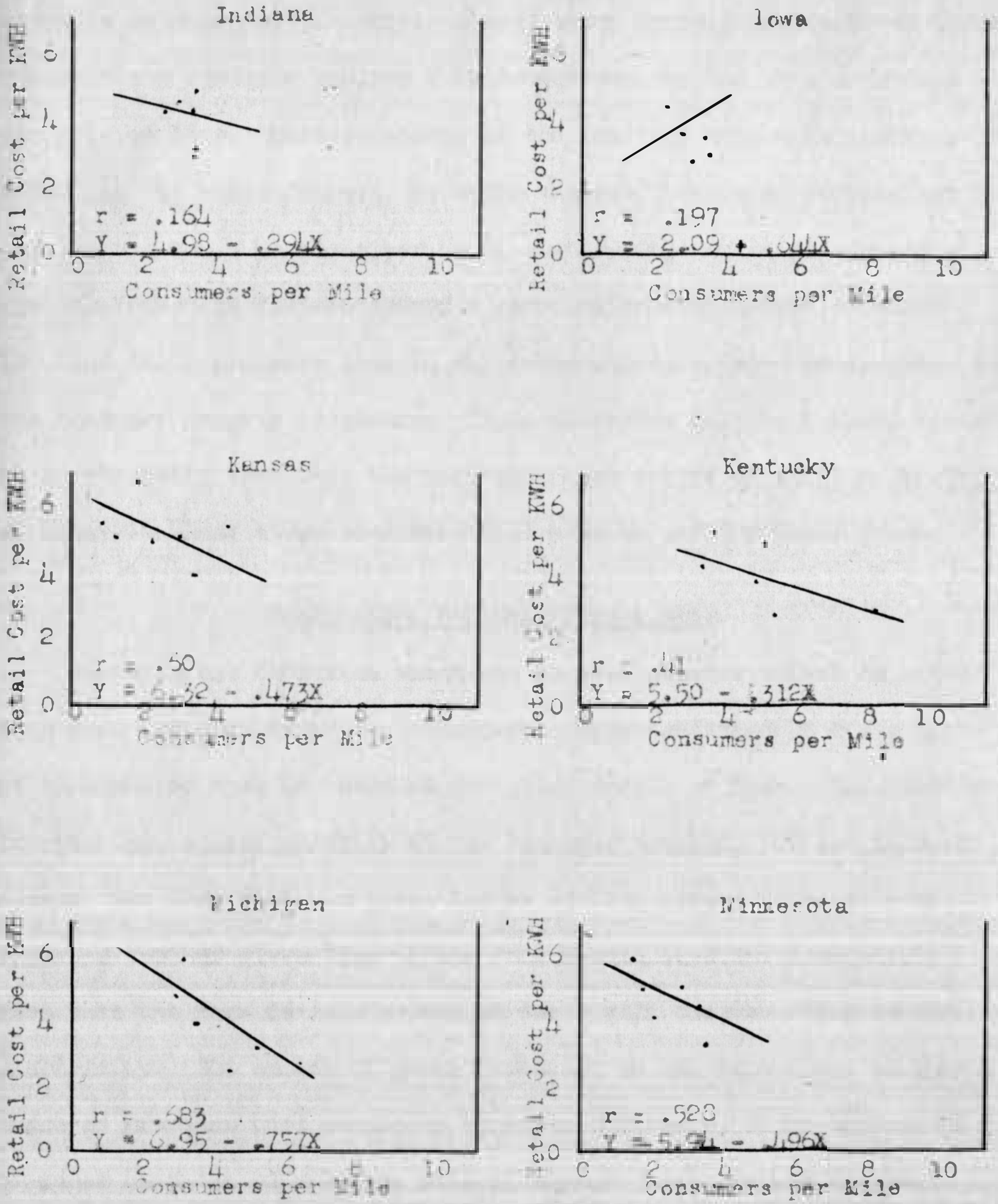

Fig. Xb. Regression lines showing the effect that density of consumers has on retail rates charged by coops from various states. "r" indicates correlation coefficient. Y indicates equation of line.

Illinois, and Indiana, the density of all the cooperatives within each state is very nearly the same. Almost every cooperative in these three states has a consumer density falling between two and five consumers per mile of line. This variation is too small to have a noticeable effect on the rates charged, so there was practically no correlation between the two. On the other hand, states with a greater variation such as Idaho and Alabama showed a correlation coefficient of about .78, and the regression line in all cases showed a decrease in rates as the consumer density increased. It is therefore safe to conclude that it is generally true that the more consumers served on a given length of line, the less these consumers will have to pay for their power.

Consumption Per Mile Versus Rate

There is one condition which has an even greater effect on rates than does the density of the consumers. This condition is the amount of electricity that is consumed per given length of line. This factor is sometimes almost parallel to the consumer density, but not in most cases. The fact that one given length of line serves twice as many farms as another given line of the same length does not necessarily mean that the more densely populated farms will consume twice as much electricity. The amount of power purchased by one farmer may be many times as great as that purchased by another farmer. It is the amount of power that can be sold per unit of expense that has the greatest effect on balancing the costs and revenues.

To prove or disprove this point, more regression lines and correlation coefficients were calculated from points plotting the rates against the amount of electricity sold per mile of line constructed, Figure XI. The same cooperatives from the same thirteen states that were used in the study of rates versus consumer density were used in the study of consumption versus rate. It was immediately clear that the consumption versus rate plotted points with a higher correlation coefficient than did the density versus rate. The states of Iowa and Indiana, which in the previous study showed practically no correlation, now had correlation values of .88 and .74 respectively, both of which are relatively high coefficients; and the regression line showed a definite decrease in rate with an increase in consumption. Even the state of Illinois showed a correlation of .4 and the regression line, which had in the density versus rate study showed an increase in rate with increase in density, showed a definite decrease in rate with an increase in consumption. In no state, regardless of location, did the regression line show an increase in rate with increased consumption. From these observations it is safe to conclude that the amount of electricity that is consumed per mile of line does have an effect on the rate that is charged.

The consumption of electricity per mile of line is of course very closely related to two of the other factors studied, namely the density of consumers of a cooperative and the age of that same cooperative. New members are not usually very high consumers. When a farmer first

C O N S U M P T I O N   P E R   M I L E   vs.   R A T E

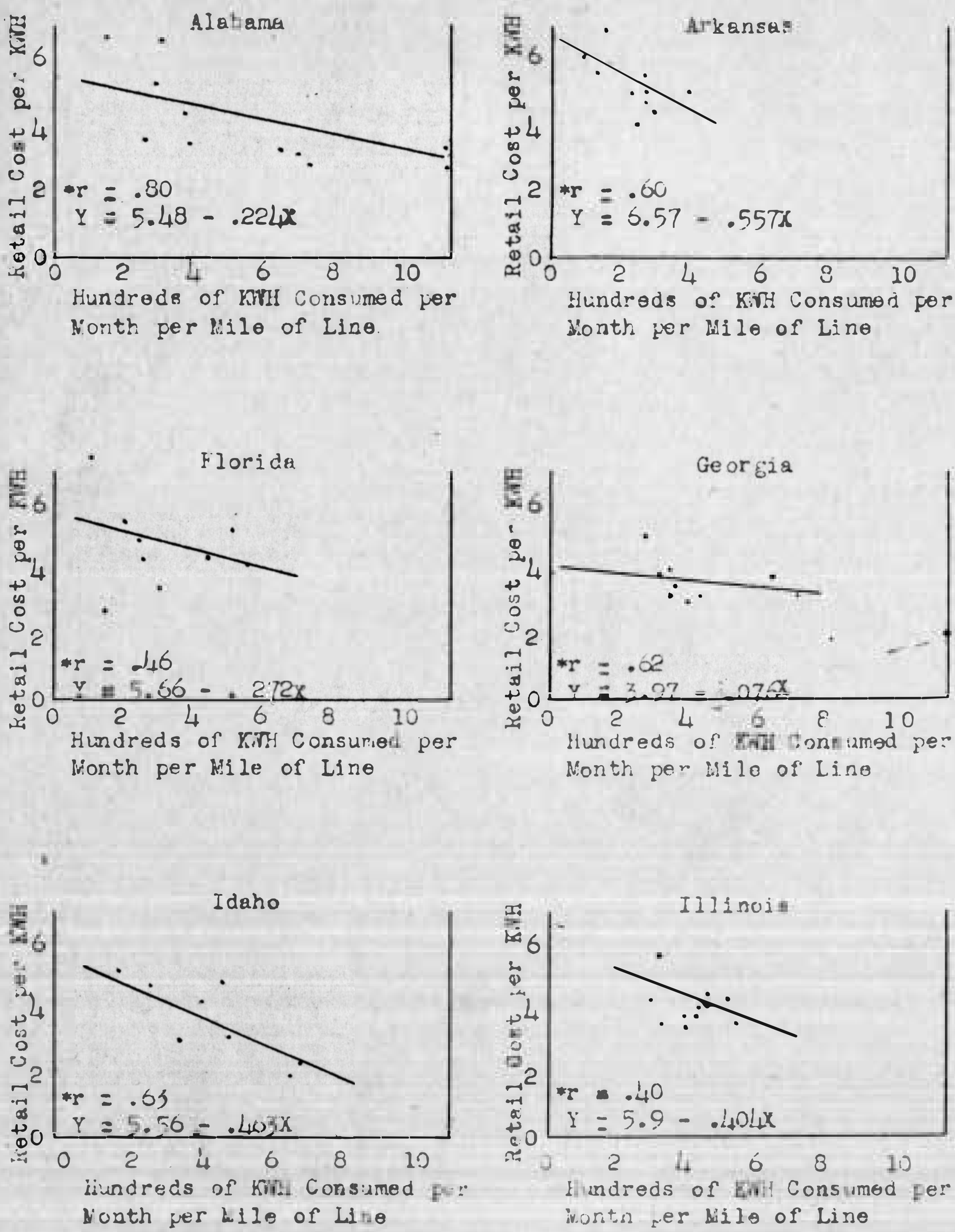

Fig. XIa. Regression lines showing the effect that consumption per mile has on retail rates charged by coops from various states. *r indicates correlation coefficient. Y indicates equation of line.

CONSUMPTION PER MILE vs. RATE

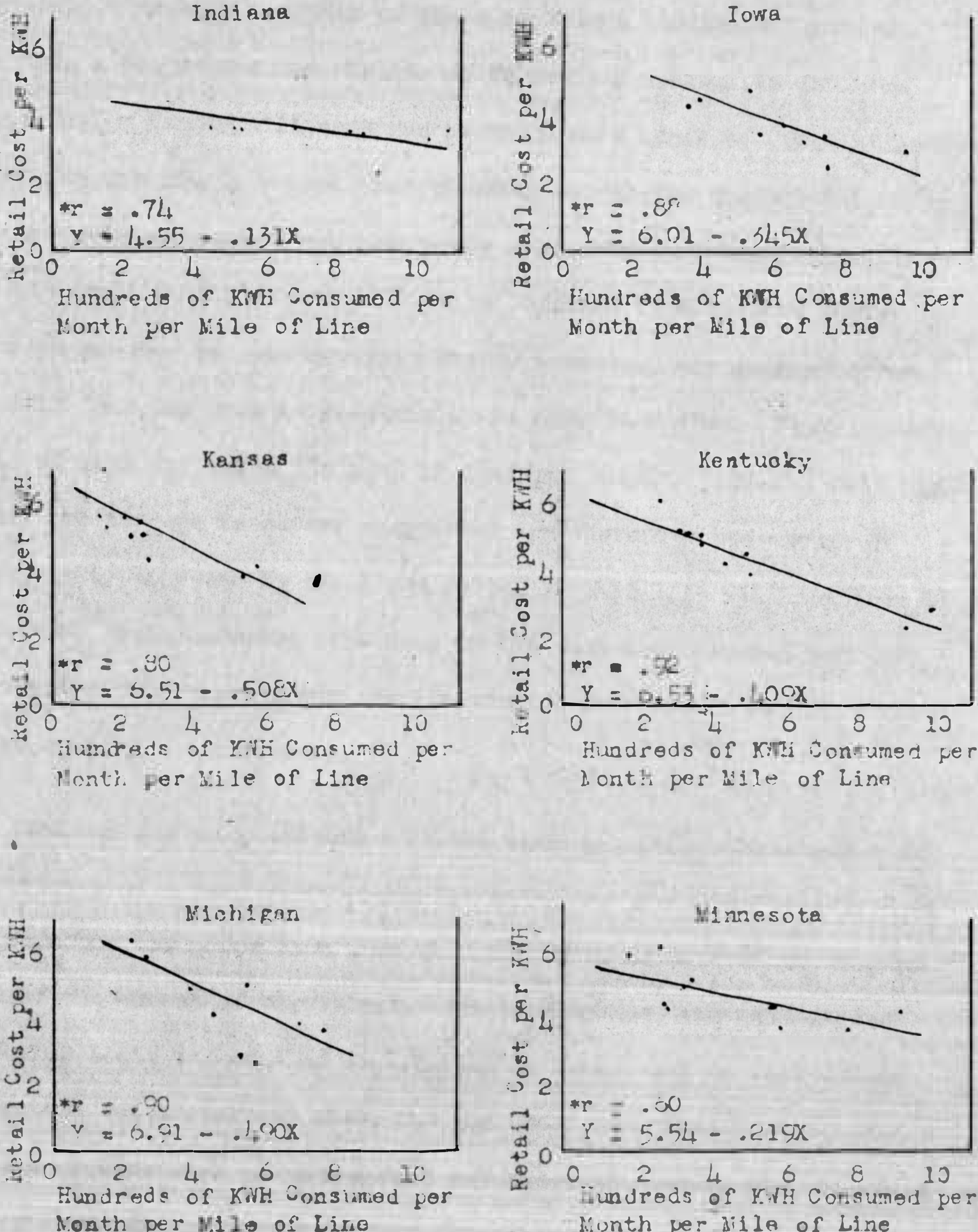

Fig. XIb. Regression lines showing the effect that consumption per mile has on retail rates charged by coops from various states. *r indicates correlation coefficient. Y indicates equation of line.

receives the opportunity to enjoy the benefits of electricity, his power load usually consists of the more common appliances such as lights, a few motors and various other smaller units. It is often true that a farmer will continue to use a more obsolete piece of equipment for the simple reason that it still serves the purpose for which it was made and is not yet completely worn out. Not until this piece of equipment does wear out will it be replaced by a new and better machine powered by electricity. For this reason, the process of completely changing over to electricity is sometimes slow. Thus, a given mile of line may reach its peak of consumer density within a very short time, but its age is always increasing and therefore the amount of electricity consumed by the farms served by that line will continue to increase. This increase cuts down on the cost per kilowatt hour of delivering this electricity, so a resultant decrease in retail rates is enjoyed by the consumers.

The one factor which has a direct bearing on the retail rates of electricity of a cooperative association is the wholesale rate of cost of producing the power that must be borne by the association. Regardless of the amount of electricity that is consumed, the initial and operating costs and cost of liquidation of debts must be included in the retail rates over and above the wholesale rate that must be paid for the electricity. An added mill per kilowatt hour on the wholesale rate will naturally result in an added mill per kilowatt hour on the retail rates. The individual associations do not have a very great amount of control over the wholesale rates, so they must establish their retail rates accordingly. They do, however, have the privilege of generating their own power. Whether or not a given cooperative association could profit by generating its own power instead of buying it is beyond the scope of this study. It is, however, important to consider the wholesale rate when making a study of the retail rates.

Many other minor items will have an indirect bearing on the rates which an individual cooperative association will charge for its electrical energy. The terrain of the land will affect the cost of building the line and may cause the necessity of extra line to follow the only convenient route. The type of soil will partly determine the cost of excavating for the poles. Geographical location will have an effect on the transportation costs of delivering the goods and equipment to the cooperative and accessibility of roads will help determine the cost of distributing the goods within the cooperative. These and many others may be important items for an individual concern to consider but they will all vary from one location to another, making it impossible to apply them to the general rates of all cooperatives.

A POSSIBLE AID TO A SOLUTION

It is evident that the process of buying and distributing electricity to rural consumers is none other than a form of business. It must operate as a business, and, to produce its product at the lowest price possible it must operate at the highest degree of efficiency. The total cost of operating must be held at a minimum, this cost being distributed over as great an amount of salable products as possible. The customers must utilize as much power as is efficient in their farming operations. To acquire this it is necessary to have organization within the administration to assure proper distribution and education among the consumers to assure proper consumption.

An important requirement for gaining proper utilization by the consumers is the presence of a farm service department. The men in the farm service department work on a straight salary basis, and their program is based on the premise that the job of building load on rural lines is not primarily a merchandising job of operating electrical companies, but a job of education. They do not read meters, sell merchandise, promote new extensions, or secure the rights of way; their entire time is devoted to educating rural customers, especially farmers, to the many advantages and uses of electric service and in cooperating with various agencies in assisting farm people to secure the maximum benefits from electricity.

The general supervision and planning of the farm electrification activities of the company is carried on by the farm service supervisor at the general office. The major responsibilities of a farm supervisor are to cooperate with other departments of the company in the correlation of all activities associated with the extension and use of electric energy on the farm. He must cooperate with various organizations outside the company such as extension divisions of agricultural experiment stations, 4-H clubs, vocational agriculture groups, and with such individuals as county agents, and Smith-Hughes teachers to promote meetings and educational discussions in an effort to increase proper utilization of electric power on the farm.

The farm service department will usually include a group of farm advisors who are in a position to make direct contact with the customers. The duties of these advisors are numerous and vary with the immediate needs of this territory, but in general he must discuss with farmers all phases of agricultural operation, always keeping in mind the part electricity will play, and to stress the advantages of electrical operation over other methods of operation and furnish any information on types of motors, installation and various equipment. He may conduct schools and demonstrations on proper and adequate wiring and power utilization. He must attempt to help the customer thereby promoting goodwill between producer and consumer. The advisor's aim should be that of building toward a farm management system of progressive electrical development. A well-organized administration and farm service department will do much toward a more efficient power utilization program among rural consumers which will result in cheaper and more satisfactory service to the consumers.

SUMMARY

Since the beginning of the distribution of electrical energy for public consumption, the problem of financial stability of the producer has always been present. The important phase of the problem is establishing a return from the consumers sufficient to run the business on a paying basis. The electricity must be sold in territories where the demand will be high enough to insure a sufficient amount of revenue to cover costs.

The first generating plants to distribute electrical energy sold their power to city consumers where the consumption was ample to permit low rates that still covered all costs. Some doubt as to whether or not the energy could be distributed to rural areas at a rate low enough to permit normal consumption existed at the time when the industry was at an early development stage. However, improvements in operation and construction procedures and the introduction of numerous electrical appliances and equipment permitted a cost and revenue balance that called for the installation of distribution lines to almost every rural area where there was a reasonable demand. The improvements are continuing to bring down installation costs and the demand for electrical energy is growing steadily. Even the residents of the sparsely populated areas of the west where no one expected to see the introduction of electric lines may now look forward to the day when they too may enjoy the benefits of electrical appliances.

In the rural areas already electrified the revenue must take care of the operation, upkeep of equipment, and liquidation of debts. The rates established in a cooperative association must be set at a point which will cover these costs and pay off a reasonable amount on the incurred debt each month without charging the customers an unreasonable amount for the electrical energy. Every possible means of establishing operating practices that will result in increased profits without extra consumer burdens should be adopted by the association.

The results of this study show that from the economic standpoint the organizations charging the lowest rates are those which are selling the greatest number of kilowatt hours of energy per unit of investment costs. Therefore, the planning procedure of a cooperative should be one that includes the promotion of proper utilization of electrical energy by the consumers to a point where every customer is utilizing as much electricity as it is feasible for him to use while operating at the highest degree of efficiency.

To accomplish good means of power utilization by the consumer, a farm service department should be included in every cooperative association. The members of this department would be responsible for building up good will between the administration and the customers and advise the farm consumers on all agricultural problems, always keeping in mind that his primary purpose is to promote proper power utilization in a manner which will increase the general welfare of both producer and consumer.

Problems of retail rates have been solved to a degree which enables the distribution of power to most rural areas that have a demand for it. The problem now exists in continuing the operational improvements and the increase in power utilization efficiency to promote a general decrease in the cost to the consumers. The rural public has enjoyed a sudden increase in their standard of living with the introduction of electrical energy at a feasible rate. They should, in the future, enjoy a gradual increase in their general welfare by a reduction in these rates.

BIBLIOGRAPHY

_____, *Costs and Uses for Electricity on South Dakota Farms.* South Dakota Agricultural Experiment Station Bulletin 259. June, 1929.

Coyle, David Cushman. *Electric Power on the Farm.* Washington, D. C., United States Government Printing Office. 1936.

Earp, Unus F. *Rural Electrification Engineering.* New York, McGraw-Hill Book Company, Inc. 1950

Rall, Udo,. *Cooperative Rural Electrification in the United States.* Pan American Union Division of Agricultural Cooperation. Washington, D. C., Series 15. July, 1940.

Rural Electrification Administration. *Report of Rural Electrification Administration.* Washington, D. C., United States Government Printing Office. 1938.

Rural Electrification Administration. *Rural Electrification on the March.* Washington D. C., United States Government Printing Office. 1938.

Schaenzer, J. P. *Rural Electrification.* Milwaukee, Bruce Publishing Company. 1949.

Tripp, Guy E. *Electric Development as an Aid to Agriculture.* New York, The Knickerbocker Press. 1926.

United States Department of Agriculture. *Rural Electrification after the War.* 1945.

ACKNOWLEDGMENT

The writer wishes to express his sincere gratitude to Mr. H. H. DeLong, Head, Department of Agricultural Engineering, and to other members of the Department of Agricultural Engineering for their criticisms and invaluable suggestions that were offered during the preparation of this thesis.